

II. "Tonometrical Observations on some existing Non-harmonic Musical Scales." By ALEXANDER J. ELLIS, B.A., F.R.S., assisted by ALFRED J. HIPKINS (of John Broadwood and Sons). Received October 30, 1884.

Musical Scales are said to be Harmonic or Non-harmonic according as they are or are not adapted for playing in harmony.

Most accounts of non-harmonic scales, such as the Greek, Arabic, and Persian, either (1) are derived from native theoreticians, who give the comparative lengths of the strings for the several notes, whence, on the assumption that the numbers of vibrations are inversely proportional to the lengths (which is only approximately correct in practice), the intervals from note to note are inferred; or (2) are attempts to express the effects of the intervals by the European equally tempered scale. The former when reduced, as in Professor J. P. N. Land's "Gamme Arabe," 1884, is the best that can be done without hearing the scales themselves. The latter is utterly delusive and misleading.

Having about 100 tuning-forks, the pitch of each of which has been determined by Scheibler's forks (see "Proc. Roy. Soc.," June, 1880, vol. 30, p. 525), and having had an opportunity of hearing the notes themselves produced on various instruments, and having had the great advantage of being assisted by Mr. A. J. Hipkins's musical ear, which is wonderfully acute to detect and estimate minute differences of pitch, and without which I could have done little,\* I have been able, I believe for the first time, to take down the actual pitch of the notes in various existing non-harmonic scales far better than it was possible to do with the siren or the monochord, which are not only difficult to manipulate and to carry about, but at the best are very apt to mislead. Where it was impossible actually to hear the sounds, I carefully measured the comparative vibrating lengths of the strings producing the notes on fretted instruments, whence, with by no means the same certainty, the scales could be inferred. But I have not here noted these measurements or their results, unless I could contrast them with the intervals obtained by measuring the actual pitch of the notes produced on the instruments themselves, as in the cases of India and Japan.

But the mere statement of the numbers of vibrations, or of the vibrating lengths of the strings producing a scale, conveys no musical notion whatever to a musician. He wants to know how many equally

\* Throughout this paper, "we" and "us" relate to Mr. Hipkins and myself jointly, and all measurements of numbers of vibrations made by us rest on the judgment of Mr. Hipkins's ear with respect to the position of the note heard between two forks, of which I had previously determined the pitch, or their Octaves.

tempered Semitones, or parts of such Semitones, are contained in the interval, so that he can realise it somewhat, as compared with the notes of a modern piano, which are intended to be tuned in equal temperament.\* This transformation is easily effected by the following brief table, premising that for brevity I use *cent* for the hundredth part of an equally tempered Semitone, of which there are twelve to the Octave.

To convert tabular logarithms into cents, and conversely—

Cents.	Logs.	Cents.	Logs.	Cents.	Logs.	Cent.	Logs.
100	.02509	10	.00251	1	.00025	.1	.00003
200	.05017	20	.00502	2	.00050	.2	.00005
300	.07526	30	.00753	3	.00075	.3	.00008
400	.10034	40	.01003	4	.00100	.4	.00010
500	.12543	50	.01254	5	.00125	.5	.00013
600	.15051	60	.01505	6	.00151	.6	.00015
700	.17560	70	.01756	7	.00176	.7	.00018
800	.20069	80	.02007	8	.00201	.8	.00020
900	.22577	90	.02258	9	.00226	.9	.00023
1000	.25086						
1100	.27594						
1200	.30103						

take the logarithm of the interval ratio and seek the next least in the first column of the table; then the next least to the difference, and so on, taking the cents opposite. Generally it suffices to take to the nearest cent, as that expresses an insensible interval. Thus, if the numbers of vibrations are 440 and 528, the difference of their logs. is .07918; the next least in the first column, .07526, gives 300 cts., with remainder, .00392; the next least to which in the second column, .00251, gives 10 cts., and remainder, .00141; the next least to which in the third column, .00125, gives 5 cts., and remainder, .00016, which in the fourth column gives .6 ct. Hence the interval is 315.6 cts., for which usually 316 cts. is sufficient to write. Now this shows that the interval contains 3 equal Semitones, and 16 hundredths of a Semi-

\* The first person to propose the measuring of musical intervals by equal Semitones was, I believe, de Prony, but I have not been able to see his pamphlet; the next was the late Professor de Morgan ("Cam. Phil. Trans.", x, 129), from whom I learned it, and I employed it in the Appendix of my translation of Helmholtz, by the advice of Mr. Bosanquet. Having found that two places of decimals sufficed for most purposes, I was led to take the second place, or hundredth of an equal Semitone as the unit, and I have extensively employed this practice, here for the first time published, with the greatest advantage. In fact, I do not know how I could have expressed the results of the present investigation in any other brief and precise, and at the same time suggestive, method.

tone more. It is therefore the just minor Third, and it is written between the notes that form it, thus: *A 316 C.*

It is convenient for comparison with what follows, to have the following just intervals expressed in cents:—

Intervals.	Cents.	Intervals.	Cents.
The Skhisma .....	2	Just major Third, $\frac{5}{4}$ .....	386
The Comma of Didymus, $\frac{8}{7} \cdot 0$	22	Pythagorean major Third, $\frac{8}{7} \cdot 1$	408
The Pythagorean Comma ..	24	Grave Fourth, $\frac{32}{27} \cdot 0$ .....	476
The Septimal Comma, $\frac{6}{5} \cdot 3$ ..	27	Just Fourth, $\frac{4}{3}$ .....	498
Quartertone .....	50	Septimal Fifth, $\frac{7}{5}$ .....	583
Small Semitone, $\frac{25}{24}$ .....	70	Tritone, $\frac{45}{32}$ .....	590
Pythagorean Limma, $\frac{256}{243}$ .....	90	Grave Fifth, $\frac{40}{27}$ .....	680
Small Limma, $\frac{125}{112}$ .....	92	Just Fifth, $\frac{5}{4}$ .....	702
Diatonic Semitone, $\frac{16}{15}$ .....	112	Acute Fifth, $\frac{25}{24}$ .....	724
Pythagorean Apotome .....	114	Just minor Sixth, $\frac{8}{7}$ .....	814
Great Limma, $\frac{27}{25}$ .....	134	Just major Sixth, $\frac{5}{4}$ .....	884
The Trumpet $\frac{3}{2}$ Tone, $\frac{12}{11}$ .....	151	Pythagorean major Sixth, $\frac{27}{25}$	906
The minor Second, $\frac{10}{9}$ .....	182	Natural minor Seventh, $\frac{7}{6}$	969
The major Second, $\frac{9}{8}$ .....	204	Minor Seventh, $\frac{16}{9}$ .....	996
Septimal minor Third, $\frac{7}{6}$ .....	267	Just major Seventh, $\frac{15}{8}$ .....	1088
Pythagorean minor Third, $\frac{23}{20}$ .....	294	Pythag. major Seventh, $\frac{243}{128}$	1110
Just minor Third, $\frac{6}{5}$ .....	316	Octave .....	1200

In each scale I give the measured number of vibrations with, occasionally, the millimetres in the vibrating lengths of string, the cents in the interval from note to note, and the sum of those cents from the lowest note to the note considered. From the latter, considering the lowest note to be *c* in all cases, it is easy to deduce the name of the nearest equally tempered note, and show how many cents must be added to it or subtracted from it to give the note heard, by remembering that—

<i>c</i>	<i>c</i> $\sharp$ or <i>d</i> $\flat$	<i>d</i>	<i>d</i> $\sharp$ or <i>e</i> $\flat$	<i>e</i>	<i>f</i>	<i>f</i> $\sharp$ or <i>g</i> $\flat$	<i>g</i>	<i>g</i> $\sharp$ or <i>a</i> $\flat$
=0	100	200	300	400	500	600	700	800
				<i>a</i>	<i>a</i> $\sharp$ or <i>b</i> $\flat$	<i>b</i>		
				900	1000	1100		

It must be borne in mind that I give the actual intervals heard from or measured on actual instruments, and that these, we may safely say, *never* represent the intervals intended by the tuner, within from 5 to 20 cents either way, on account of the extreme difficulty of precise tuning, especially when the intervals are non-harmonic. European ears are at present satisfied, on our theoretical equally tempered scale, with Fifths too flat, and Fourths too sharp by 2 cts., with major Sevenths too sharp by 12 cts.; major Thirds too sharp by

14 cents, and major Sixths too sharp by 16 cents, while of course the minor Sixths are 14 cts. too flat, and the minor Thirds 16 cts. too flat. That is to say, these would be the errors if the tuning were perfect. The practice, as I have determined by actual measurement, is necessarily far from being restricted to these limits. Hence the results here given have to be compared with many other results from other instruments of the same kind, tuned by different tuners before the intended intervals could be, if they ever can be, satisfactorily determined. In the meantime we know that native ears have actually been satisfied by the intervals here given.

It must also be remembered that as the tones heard were often exceedingly brief (as from wood harmonicons), or very impure, being mixed with inharmonic proper tones (as from metal harmonicons, kettles, gongs, &c.), it was generally impossible to count beats, and often even exceedingly difficult to tell within what pair of forks the note heard really lay, so that there is a possible error of two vibrations occasionally, but, thanks to the acuteness of Mr. Hipkins's ear, it is not probable that the error at any time exceeds one vibration in a second. The number determined is therefore purposely given only to the nearest integer.

#### I. ARABIA AND SYRIA.

The theoretical account of Arabic scales is admirably given in Professor Land's "Gamme Arabe." It there appears that one Zalzal, more than a thousand years ago, being dissatisfied with the ordinary division of the Fourth, as—

<i>C</i>	204	<i>D</i>	90	<i>E</i> ♭	114	<i>E</i>	90	<i>F</i>
0		204		294		408		498

(where the figures between give the number of cents from note to note, and the figures below give the number of cents from the lowest note), introduced a division, which, carried out to the Octave, amounted to—

<i>C</i>	204	<i>D</i>	151	q <i>E</i>	143	<i>F</i>	204	<i>G</i>	151	q <i>A</i>	143	<i>B</i> ♭	204	<i>C</i> ,
0		204		355		498		702		853		996		1200

where q*E* and q*A* mean about a quarter of a tone *less* than (or before coming to) *E* and *A*, and in the same way *E*q, *A*q would mean a quarter of a tone *beyond* *E* and *A*. (In musical notes q will become ♫, a turned ♯.)

In later periods this was tempered to a division of the Octave into 24 equal Quartertones, as we learn from Eli Smith, an American missionary at Damascus, who translated Meshāqah's treatise in the "Journal of the American Oriental Society," 1849, vol. i, pp. 171–217. The scale therefore becomes—

<i>C</i>	200	<i>D</i>	150	<i>qE</i>	150	<i>F</i>	200	<i>G</i>	150	<i>qA</i>	150	<i>B<sub>b</sub></i>	200	<i>C</i> ,
0		200		350		500		700		850		1000		1200

although in the Middle Ages a different scale prevailed in Arabia, to which I need not further allude. Now between Zalzal's time and this mediæval alteration the Crusaders brought the Syrian bagpipe to England, and after it had passed out of fashion in England, it became the national instrument of the Highlands of Scotland.

Such an instrument, made by Maedonald, of Edinburgh, and obligingly played to us by its possessor, Mr. Charles Keene, the well-known artist, yielded on examination the following results :—

#### Highland Bagpipe.

Vib.* .....	395	441	494	537	587	662	722	790	882
From vib. ..	<i>g'</i> 191	<i>a'</i> 197	<i>b'</i> 144	<i>c''</i> 154	<i>d''</i> 208	<i>e''</i> 150	<i>f''</i> 156	<i>g''</i> 191	<i>a''</i>
Sums from <i>a'</i> . — 191	0	197	341	495	703	853	1009	1200	
Tempered .. — 200	0	200	350	500	700	850	1000	1200	
Notes .....	<i>c</i>	<i>d</i>	<i>qe</i>	<i>f</i>	<i>g</i>	<i>qa</i>	<i>bb</i>	<i>c'</i>	

The tempered form, therefore, coincides with the Damascus form of Zalzal's scale, which I did not discover till long afterwards. The theory of this scale is lost, but it is usual to make *g'* to *a'* rather less than a whole tone, while the two drones, an Octave and two Octaves below *a'*, necessitate a pure Fifth, *a'* 702 *e''*. Zalzal divided a Pythagorean minor Third of 294 cents into 151 and 143 cents; the modern instrument divides the just minor Third 316 cents, probably, into 151 and 165 parts. We thus get a possible rationalised form of the bagpipe scale, the first attempted, so far as I know. As usual in bagpipe music, I begin the scale on *a'*. I have calculated the vibration to the same base *a'* 441 vib., for both tempered and rational vibrations, to show how close they are to the observed :—

#### Rationalisation of the Bagpipe Scale.

Observed vib. . 441	494	537	587	662	722	790	882
Tempered vib. . 441	495	540	587	661	721	786	882
Rational vib... 441	496	541	595	662	722	794	882
Notes..... <i>a'</i> 204 <i>b'</i> 151 <i>c''</i> 165 <i>d''</i> 182 <i>e''</i> 151 <i>f''</i> 165 <i>g''</i> 182 <i>a''</i>							
Sums of cents . 0	204	355	520	702	853	1018	1200
Ratios .....	<i>a'</i> 8 : 9 <i>b'</i> 11 : 12 <i>c''</i> 10 : 11 <i>d''</i> 9 : 10 <i>e''</i> 11 : 12 <i>f''</i> 10 : 11 <i>g''</i> 9 : 10 <i>a''</i>						
Ratio from <i>a'</i> .. 1	8 : 9	22 : 27	20 : 27	2 : 3	11 : 18	5 : 9	2

\* In these tables the line "vib." contains the number of vibrations determined by us. The line "from vib." contains the notes, in this case those usually given in bagpipe music, but generally merely distinguished by Roman numerals, I, II, III, &c., with the interval between them in *cents*. The line "sums" gives the sums of these cents, interval by interval, that is, the interval between each note and the lowest. The line "tempered" shows the nearest intervals on an equally tempered scale of 24 Quartertones in the Octave. The "notes" sometimes added, as those due to taking 0 as *c*, as already explained.

## II. INDIA.

There are two distinct kinds of scales in India, those of harmonicons, most probably from hill tribes, and those of the stringed instruments belonging to the conquering race.

*Balafong* from Patna in the South Kensington Museum, a wooden harmonicon strung over a beautifully carved case, consisting of 25 bars (of which we measured 14) containing 3 Octaves and 3 notes. The Roman numerals II, III, &c., indicate the successive bars, I was not measured.

Vib. ....	158	176	194	214	233	259	279	320
From vib.....	II 187	III 169	IV 170	V 147	VI 183	VII 129	VIII 237	IX
Sums .....	0	187	356	526	673	856	985	1222
Vib. ....	320	355	391	434	484	531	582	
From vib.....	IX 180	X 167	XI 181	XII 189	XIII 160	XIV 159	XV	
Sums, less 1222..	0	180	347	528	717	877	1086	

Observe IV 356 cents, and VII 856 cents, which compare with Zalzal in I. ARABIA. All the Octaves were too sharp. The old Indian stringed instrument is the *Vina* with frets  $\frac{7}{8}$  to  $\frac{9}{8}$  inch high, so that by pressing the string behind the fret the pitch can be greatly altered. These frets are shiftable, but are usually fastened with wax. I measured the vibrating lengths of string of many, but I consider the resulting scales not sufficiently trustworthy for record here. This pressing behind the fret is constantly employed to sharpen the pitch by a quarter or half a Tone. The modern *Sitár*, which has practically superseded the *Vina*, is a very long-necked guitar with movable frets. These frets are set for the *rāg* or *rāgini* (tune, key, or mode) in which the musician is going to play. They are high enough above the finger-board to allow pressure behind to exert a sensible effect, but the ordinary method of raising the pitch is to deflect the string by moving the finger with the string transversely along the fret. As, however, the frets are properly set, this deflection is used only for grace notes at the end, suddenly raising the pitch about a quarter of a Tone and returning it to its former position.

H.H. Rája Rám Pál Singh was kind enough to bring his sitár (which he left with me), and setting it in five different manners to play Indian airs to us. After he had done so I measured the position of the frets, so that I could return them to their places. Afterwards we sounded each note, took its pitch, and determined the scale by my forks. This, I believe, is the first time that this has been done for any Indian instrument. The pitch for the open string was not the same as that used by the Rája, for these measurements were not taken till long afterwards, but the relative pitch remained the same. This string, which was an English pianoforte steel wire, replacing the Indian steel wire which was broken, was too thick, and this interfered somewhat with the setting. As I had calculated the

intervals in cents from the vibrating lengths, I add these also in millimetres to show how unsatisfactory are the results thus obtained. The I, II, &c., number the frets used which, however, begun at about the interval of a Fifth from the open string.

#### First setting of the Sitar—

Vib. lengths ...	616	554	503	452	417	380	339	316 mm.
From lengths ...	I	184	II	167	III	185	IV	140
Sums .....	0	184		351		536	676	
					V	161	VI	198
						837	1035	1155
Vib. ....	393	437	479	535	584	650	731	800
From vib. ....	I	183	II	159	III	191	IV	152
Sums .....	0	183		342		533	685	
					V	186	VI	203
						871	1074	1230

#### Second setting of the Sitar—

Vib. lengths ...	616	554	530	452	417	380	355	316 mm.
From lengths ...	I	184	II	77	III	276	IV	140
Sums .....	0	184		261		537	677	
					V	161	VI	118
						838	956	1157
Vib. ....	393	437	460	535	584	650	693	800
From vib. ....	I	183	II	89	III	262	IV	152
Sums .....	0	183		272		534	686	
					V	186	VI	111
						872	983	1232

#### Third setting of the Sitar—

Vib lengths ...	616	577	518	452	417	389	352	318 mm.
From lengths ...	I	113	II	187	III	236	IV	140
Sums .....	0	113		300		536	676	
					V	120	VI	173
						796	969	1146
Vib. ....	393	419	471	535	584	634	707	785
From vib. ....	I	111	II	203	III	220	IV	152
Sums .....	0	111		314		534	686	
					V	142	VI	189
						828	1017	1198

#### Fourth setting of the Sitar—

Vib. lengths ...	612	552	500	466	415	368	337	318 mm.
From lengths ...	I	179	II	171	III	122	IV	201
Sums .....	0	179		350		472	673	
					V	208	VI	152
						881	1033	1133
Vib. ....	397	439	486	523	594	671	737	786
From vib. ....	I	174	II	176	III	127	IV	220
Sums .....	0	174		350		477	697	
					V	211	VI	162
						908	1070	1181

#### Fifth setting of the Sitar—

Vib. lengths ...	607	574	492	461	408	384	332	312 mn
From lengths ...	I	97	II	267	III	113	IV	212
Sums .....	0	97		364		477	689	
					V	105	VI	252
						794	1046	1154
Vib. ....	395	416	488	525	594	620	737	784
From vib. ....	I	90	II	276	III	127	IV	214
Sums .....	0	90		366		493	707	
					V	74	VI	299
						781	1080	1187

I would draw attention to the great difference in all cases between the two last intervals, I to VII, and I to VIII, as calculated from the lengths of the strings and the number of vibrations. This arose from the string lying naturally further above the frets for the last notes, and hence the tension being more increased by pressing the string to the fret. Also observe how nearly III approaches to 350 cents in the first, fourth, and fifth settings, and VI to 850 cents in the first, second,

and third settings, taking all from the intervals heard. The Indian system of scales is very complex, and differs much from the European.

### III. SINGAPORE.

Mr. Hipkins received a *Balafong* or wood harmonicon direct from Singapore, consisting of 24 bars forming 3 Octaves and 3 notes. We measured the central Octave, beginning at bar 8, as follows:—

Observed vib....	312	344	382	427	470	523	569	626
From vib. ....	I	169	II	181	III	193	IV	166
Sums .....	0	169	350	543	709	894	1040	1205
Tempered vib..	312	340	382	429	467	525	572	624
From vib. ....	I	150	II	200	III	200	IV	150
Sums .....	0	150	350	550	700	900	1050	1200

The tempered form is given to show that this is one of the Quarter-tone systems, and the tempered vibrations were calculated to show how near they are to the observed.

### IV. BURMAH.

The *Patala* or wood harmonicon of 25 small neat bars in the South Kensington Museum, No. 1630—'72, "Engel," p. 16, who gives the scale wrongly. We began at the seventh bar from the end, and took an Octave thus:—

Vib. ....	300	332	367	408	451	504	551	616
Bars ....	I	176	II	174	III	183	IV	174
Sums .....	0	176	350	533	707	899	1053	1246

The Octave is very sharp, and bars 15, 16, 20 were sharp Octaves of II, III, VII, bar 16 being very sharp indeed. Otherwise the Octaves were fair.

A *Balafong*, in South Kensington Museum, with a box decorated with Burmese ornaments, 22 bars, containing 3 Octaves and 1 note. Twelve bars measured from 4th to the 15th. The first 5 formed the end of an Octave.

Vib. ....	...	...	...	237	258	282	318	353
From vib. ....	...	...	...	IV	147	V	154	VII
Sums .....	...	...	...	506	653	807	1015	1196
Vib. ....	353	377	432	485	525	573	641	705
From vib. ....	VIII	114	IX	236	X	200	XI	137
Sums .....	0	114	350	550	687	838	1032	1196

The sums in the first line have been found by subtraction from that under VIII, which was assumed to be the same as that under XV. The different construction of the corresponding parts of the Octave is thus shown.

The *Keay Wine* in South Kensington Museum consists of 15 kettles or gongs resembling the Javese bonangs, arranged in a circle. III\* was

cracked, and its pitch is doubtful, as was also that of V\*. II and III\*, as the latter stood, were practically identical.

First oct. vib...	303	333	334	377	416	449	506	602
From vib.....	I	163	II	5	III*	210	IV	170
Sums .....	0	163	168	378	548	680	947	1248
Second oct. vib.	602	622	648	719	796	867	990	1032
From vib. ....	VIII	57	IX	71	X	180	XI	176
Sums .....	0	57	128	308	484	632	862	934

The kettles were probably all out of tune.

### V. SIAM.

The *Ranat* in South Kensington Museum is a wood harmonicon with 19 bars, scale wrongly described in "Engel," p. 316. Bar XIII\* was of a different kind of wood, and had evidently been inserted as a substitute for the Octave of VI, but was too sharp.

First oct. vib....	323	348	379	433	491	504	585	666
From vib. ....	VI	129	VII	148	VIII	231	IX	218
Sums .....	0	129	277	508	726	771	1029	1254
Second oct. vib.	666		748		794			
From vib. ....	XIII*	201	XIV	103	XV			
Sums .....	0	201		304				

The scale is enigmatical.

### VI. WEST COAST OF AFRICA.

This is inserted out of geographical position, because it is a solitary example from Africa, and resembles those immediately preceding in character. A *Balafong* in South Kensington Museum, No. 1080, 1080a—'68, "Engel," p. 154, who describes the scale wrongly. We measured nine bars—

Observed vib..	327	357	386	445	497	547	596	654	714
From vib.....	VIII	152	IX	135	X	246	XI	191	XII
Sums.....	0	152		287	533	724	890	1039	1200
Tempered vib.	327	357	389	449	504	550	600	654	
From vib.....	VIII	150	IX	150	X	250	XI	200	XII
Sums .....	0	150		300	550	750	900	1050	1200

where the tempering shows that the scale belongs to the system of Quartertones.

### VII. JAVA.

The scales were observed from the instruments of the Javese Gamelang or band, at the Aquarium, in November, 1882, and formed the commencement of these investigations. We were materially assisted by work done on the same instruments (but without determining pitch) by Mr. W. Stephen Mitchell, M.A., of Gonville and Caius College, Cambridge, and by determinations with the monochord of similar instruments in Holland by Professor J. P. N. Land (who

also gave me much information), assisted by Dr. Onnes, both of Leyden. Professor Land also kindly communicated the results of the measurements by Dr. Loman and Dr. Figée, both of Leyden. These measurements of distinct instruments are annexed in a reduced form.

There are two entirely different Javese orchestras which cannot play together. We examined three sets of instruments from each—the *Gambang*, or wooden harmonicon, the *Sáron* and *Slèntem*, or metal bar harmonicons, and the *Bonang*, or set of kettles—while in Leyden a *Géndér* (another metal harmonicon) and a different *Sáron* were examined.

The first orchestra played *Saléndro*, the second *Pèlog* scales, both Pentatonic; but, as will be seen, completely different. The first had only five notes in the Octave, the second had seven, but used only five at a time, just as Europeans have twelve, but use only seven at a time. The first has no interval between consecutive notes so small as a major Second, or so large as a minor Third. The second has between two consecutive notes of its seven, approximatively two Semitones, (no Tone), three Three-quartertones, and two minor Thirds. The first is very uniform, the second very diverse in its intervals.

#### First or Saléndro Scales.

Obs. vib.		*	Out of tune.		†	Not recorded.	
Gambang .....	*268	308	357	411	470	*535	
Sáron (E. & H.) ..	272	308	357	411	471	543	
Slèntem .....	270	308	357	411	469	540	
Mean .....	270	308	357	411	470	540	
From Mean .....	I 228	II 256	III 244	IV 232	V 240	I'	
Sums .....	0	228	484	728	960	1200	
Géndér, lower oct..	I 191	II 251	III 249	IV 261	V 220	I'	
Géndér, upper oct..	I 219	II 256	III 261	IV 223	V 288	I'	
Sáron (Land) .....	I 270	II 200	III 266	IV 239	V 243	I'	
Sáron (Figée) .....	I 275	II 210	III†	IV†	V	243	I'
Tempered vib.....	270	310	356	409	470	540	
From vib. .....	I 240	II 240	III 240	IV 240	V 240	I'	
Sums .....	0	240	480	720	960	1200	

This tempered form seems to have been that aimed at. It is easily tuned when the ear has become accustomed to the flat Fourth of 480 cents. Tune up I 480 III, and III 480 V. Then from the Octave I' tune down I'—480 IV, and IV—480 II. Observe that the Fourth is flat and the Fifth sharp, and that V is nearly the natural harmonic Seventh of 969 cents. These are also points of distinction from the next set.

## Second or Pèlog Scales.

	Obs. Vibrations.			* Out of tune.							
Gambang .....	*283	*311	365	391	416	448		*532		*566	
Bonang .....	278	302	361	390	417	448		526		556	
Saron .....	279	302	360	387	414	447		524		558	
Adopted .....	279	302	361	389	415	448		526		558	
From adopted.....	I 137	II 309	III 129	IV 112	V 133	VI 278	VII 102	I'			
Sums .....	0	137	446	575	687	820	1098	1200			

	Scales.										
Pèlog .....	I 446	...	III 129	IV 112	V 411	...	VII 102	I'			
Dantsoe .....	I 137	II 550	...	...	V 133	VI 278	VII 102	I'			
Bem (E. & H.) .....	I 137	II 438	...	IV 112	V 411	...	VII 102	I			
,, (Loman) .....	I 147	II 416	...	IV 96	V 429	...	VII 112	I'			
Barang (E. & H.) .....	I 137	II 438	...	IV 112	V 133	VI 380	...	I'			
,, (Loman)....	I 151	II 426	...	IV 111	V 179	VI 333	...	I'			
Miring.....	I 446	...	III 129	IV 245	...	VI 278	VII 102	I'			
Menjoera.....	I 137	II 309	III 129	IV 523	...	...	...	VII 102	I'		
Tempered vib.....	279	304	382	395	418	443	527	558			
From vib.....	I 150	II 300	III 150	IV 100	V 100	VI 300	VII 100	I'			
Sums.....	0	150	450	600	700	800	1100	1200			

After giving the three sets of vibrations observed I give that adopted, which is the mean of the second and third set, as the Gambang was evidently rather out of tune, and then the scale of all the seven notes answering to the chromatic scale of our pianos. Then follow the names of the scales really used, formed by selecting five notes from these. Pèlog and Dantsoe (pronounce Dutch *oe* as our *oe* in *shoe*) are given only from our own observations. In Bem and Barang, Dr. Loman's observations made with the monochord in 1879 on another set of instruments are added in a reduced form. These four scales are certain. Miring and Menjoera (pronounce Dutch *joe* like the English word *you*) are conjectural restorations from imperfect indications communicated to me by Professor Land. Finally, I have added a rather hazardous tempering, and shown by calculating the vibrations from it, that it does not materially misrepresent the observed. In these scales the Fourth, IV 575 cents, is nearly the tempered Tritone 600 cents, and the Fifth, V 687 cents, is flatter even than the tempered Fifth 700 cents. This is exactly contrary to the Salêndro scale. Yet I observed one of the players selecting the right bar for his scale by holding it up and tapping it with his finger, showing that the pitch was quite familiar to him.

## VIII. CHINA.

Without entering upon any discussion on the very vexed question of Chinese music, I confine myself to giving the scales which (by the kind permission of Mr. J. D. Campbell, one of the Commissioners of Chinese customs representing China at the International Health Exhibition this year, and with the assistance of the secretary, Mr. Neumann), we were able to have played to us by the Chinese

musicians attached to that court, in July and August, 1884, at four specially arranged meetings, on their own instruments, together with observations on a duplicate of one of them at the South Kensington Museum, and a set of bells belonging to Mr. Hermann Smith.

1. *Transverse Flute* or *Ti-tsü*, with seven finger holes and an embouchure, open at both ends. Probably in actual playing some of the notes may have been varied by half or quarter covering of the finger-holes. The Heptatonic scale played is given first, and then the notes selected for the more usual Pentatonic scale.

Vib. ....	240	266	292	311	352	401	454	479
From vib. ....	I 178	II 161	III 109	IV 214	V 226	VI 215	VII 93	I'
Sums.....	0	178	339	448	662	888	1103	1196
Pentatonic ....	I 178	II 270	...	IV 214	V 226	VI 308	...	I'

2. *Oboe* or *So-na*, played with a short reed, having seven finger-holes in front and two thumb-holes behind, a loose brass cone of considerable size covered the lower end. Said to be a modern instrument. Sound and intervals resembling the bagpipes.

Vib.....	400	435	475	516	578	640	719	808
From vib. ....	I 145	II 152	III 143	IV 197	V 176	VI 201	VII 202	I'
Sums .....	0	145	297	440	637	813	1014	1216
Tempered vib...	400	436	476	519	582	635	713	800
From vib. ....	I 150	II 150	III 150	IV 200	V 150	VI 200	VII 200	I'
Sums .....	0	150	300	450	650	800	1000	1200

On this instrument as thus played there was nothing approaching a Fourth of 498 cents, or a Fifth of 702 cents. It must have been modified in playing to work with the flute. Both were orchestral instruments.

3. *Reed Mouth Organs* or *Shéng* (rhymes to *sung*, and often so called), a gourd with its top cut off, and covered with a flat board, in which were inserted 13 pipes, 11 of which had free reeds, which sounded on blowing (or sucking) through the mouth-hole, and stopping a hole in the pipe which the player intended to sound. The lengths of the pipes are ornamental, an internal slot determining the real lengths. The two "dummies" were for holding.

First oct. vib....	450	508	547	600	680	760	820	899
From vib. ....	I 210	II 128	III 160	IV 217	V 193	VI 132	VII 159	I'
Sums .....	0	210	338	498	715	908	1040	1199
Second oct. vib.	899	1017	1110	1232				
From vib. ....	I' 214	II' 151	III' 182	IV'				
Sums .....	0	214	365	547				
Tempered vib...	450	505	551	601	674	757	825	900
From vib. ....	I 200	II 150	III 150	IV 200	V 200	VI 150	VII 150	I'
Sums .....	0	200	350	500	700	900	1050	1200

Here we have a perfect Fourth, IV 498 cents, and a good but sharp Fifth, V 715 cents. But the instrument, if in tune (small free reeds easily fall out of tune), belonged to the Quartertone system.

4. *First Chime of Small Gongs* or *Yan-lo*, a set of 10 small gongs about the size and shape of cheese-plates, arranged with I at the top, II, III, IV in the first row, from left to right behind, where they were struck with a wooden hammer, and then V, VI, VII in the second, and VIII, IX, X in the third row, all hung in a square wooden frame. The Chinese musician played in the order of pitch, omitting IX and I.

Vib. ....	449	495	555	568	630	663	703	712	830	902
From vib.....	VIII	169	V	198	II	40	IX	179	IV	88
Sums.....	0	169		367		407		586		674
Played .....	0	169		367		...		586		795

Here again there is no approach to a Fourth of 498 cents, or a Fifth of 702 cents.

5. *Second Chime of Small Gongs* or *Yan-lo*, in the S. K. Mus., "Engel," p. 193, who describes the scale wrongly. Although the instrument is of the same appearance as the last, the scale was entirely different, and the compass did not reach 750 cents. We seemed to make out three possible scales which are annexed, but we have no means of knowing if they were designed. One extends to a sharp and another to a flat Fifth, whilst the third reaches an exact Fourth. The gongs are numbered as in No. 4.

Vib. ....	794	818	912	926	1011	1022	1114	1116	1198	1216
From vib.....	I	52	II	188	III	26	IV	152	VI	19
Sums.....	0	52		240		266		418		437

Possible scales

To sharp Fifth	I	240	...	III	178	...	VI	171	...	...	IX	123	X
Sums .....	0			240			418				589		712
To flat Fifth	...	...	II	188	III	178	...	VI	168	...	V	152	...
Sums .....	0			188			366				584		686
To Fourth.....	...	...	III	197	...	...	VIII	152	...	IX	149	...	VII
Sums .....	0						197				349		498
Tempered .....	0						200				350		500

The last is therefore like the first tetrachord in the bagpipe scale, dividing the Fourth into a Tone and two Three-quartertones. There are, however, several curious intervals.

VI 19 VIII nearly a comma of 22 cents.

III 26 IV nearly  $\frac{1}{8}$  of a major Tone of 204 cents.

I 52 II exactly  $\frac{1}{4}$  of a major Tone of 204 cents.

II 188 III and III 178 IV are both nearly the minor Tone of 182 cents.

I 240 III is an exact pentatone, or  $\frac{1}{5}$  Octave, as in the tempered Javese Saléndro scale.

II 385 VIII is an excellent major Third of 386 cents.

I 586 V and I 589 IX are both nearly the Zaïd of 588 cents, on the second string of the Arabic lute.

I 738 VII, the complete compass, is exactly the 49th harmonic reduced to the same Octave, which is of course only a curious coincidence.

6. *Dulcimer* or *Yang-chin*, exactly like the ordinary dulcimer (see figure in Grove's "Dictionary of Music," i, 469), with four wires to each note forming two Octaves, the longer wires passing under the bridge which limits the shorter. It is struck with elastic hammers. The instrument being out of tune was tuned for us by the musician who played No. 7, according to the Chinese names of the scale in Dr. William's *Middle Kingdom*, which are there interpreted as the major scale of  $E\flat$ . If the conjectural just scale be correct, this would be the scale of  $B\flat$  major, beginning on its second note  $C$ , and is therefore comparable to the Japanese Ritsusen, which is the scale of  $C$  major begun on its second  $D$ .\*

Chinese names...	Ho	sz <sup>*</sup>	f	chang	ché	kung	fan	liu.
Vib. ....	205	226	240	272	300	340	364	409
From vib. ....	I 169	II 105	III 217	IV 170	V 217	VI 118	VII 202	I
Sums .....	0	169	274	491	661	878	996	1198

Conjectured Just

Vib. ....	205	228	243	273	304	342	364	410
From vib. ....	C 182	D <sub>1</sub> 112	E $\flat$ 204	F 182	G <sub>1</sub> 204	A <sub>1</sub> 112	B $\flat$ 204	c
Sums .....	0	182	294	498	680	884	996	1200

Pentatonic form.	C 182	D <sub>1</sub> 316	...	F 182	G <sub>1</sub> 204	A <sub>1</sub> 316	...	c
------------------	-------	--------------------	-----	-------	--------------------	--------------------	-----	---

The tuner had great difficulty in tuning the semitones II 105 III and VI 118 VII, that is, in tuning the notes III and VII. He accomplished the second more easily than the first. The Pentatonic form consists of two disjunct tetrachords, *CF, Gc*, each divided into a Tone and a minor Third.

8. *Tamboura* or *Sien-tsu*, a three-stringed guitar with circular body and long neck without frets. The strings were tuned to 239, 266, and 400 vib., making the intervals 185 and 706 cents, meant for 182 the minor tone, between the first and second, and for 702, a Fifth, between the Second and Third, very fairly tuned indeed. The strings were plucked with bone plectrums, attached to the first joint of thumb and forefinger, and projecting like claws. The tone was good and very like a banjo. Only the following pentatonic scale was played to us:—

Vib. ....	320	357	400	480	536	642
From vib. ....	I 189	II 197	III 316	IV 191	V 312	I'
Sums .....	0	189	386	702	893	1200

\* In writing tones in Pythagorean intonation formed by a succession of just Fifths or Fourths from *C*, the ordinary letters are kept unchanged; but for just intonation it is necessary to have a series a comma lower. These have a subscript 1, as *D*<sub>1</sub>, so that, in vibrations, *D*<sub>1</sub> : *D* = 80 : 81. Similarly another series would be a comma sharper, and be written with a superior 1, as *E* $\flat$ <sub>1</sub>, so that, in vibrations, *E* $\flat$ <sub>1</sub> : *E* $\flat$  = 80 : 81.

Conjectural Just								
Vib.	.....	320	356	400	480	535	640	
From vib.	.....	C 182	D <sub>1</sub> 204	E <sub>1</sub> 316	G 182	A <sub>1</sub> 316	c	
Sums.	.....	0	182	386	702	884	1200	
Transformed sums..		498	680	884	0	182	498	

This was again so nearly just that I have conjectured a just restoration,  $CD_1E_1GA_1c$ : and if this is transformed, by beginning it with  $G$ , or by deducting 702 cents from each of the last sums (previously adding 1200 cents where needed), we obtain the scale  $G\ 182\ A_1\ 316\ C\ 182\ D_1\ 204\ E_1\ 316\ G$ , in which the intervals are precisely the same as in No. 7.

9. *Balloon Guitar* or *P'i-p'a*.—The body of the guitar was oval. There were four strings, the lowest tuned to 234 vib., and then its Fourth, its Fifth, and its Octave, but we did not test the accuracy of these intervals, which were tuned by the same musician who tuned Nos. 7 and 8. Near the nut were four large, round-backed, semi-elliptical frets, joining each other at bottom. These the player did not use. But on two examples of the S. K. Museum, I conjectured by measuring the strings, that they were intended to give such a tetrachord as—

C	204	D	90	E <sub>b</sub>	114	E	90	F
0		204		294		408		498

or their just or tempered forms. There were 12 frets on the body of the instrument. They were high but broad at the top. We did not test each, but merely took down the following pentatonic scale :—

Observed vib..	320	348	392	465	530	638
From vib. ....	I 145	II 206	III 296	IV 227	V 321	VI
Sums .....	0	145	351	647	874	1195
Tempered vib..	320	349	392	466	538	640
From vib. ....	I 150	II 200	III 300	IV 250	V 300	VI
Sums .....	0	150	350	650	900	1200

The tempered scale agrees well in all notes but V. The scale is so remarkable in every way, though it did not sound amiss, that I suspect the frets to have been inaccurately placed; they were bits of wood roughly glued on.

This completes our observations with the Chinese musicians. I measured also the vibrating lengths of strings in two other P'i-p'as, and also two Moon Guitars or *Yueh-chins* in the S. K. Museum. One of the latter seemed intended for equal temperament of 12 Semitones, and it is the only Chinese instrument which has suggested this to me; the other looked like an attempt to divide the Octave into eight Three-quartertones, and had at any rate eight tones

to the Octave forming nearly those intervals. But as I did not try these with forks I do not record them.

10. *Small Chime of Bells*, belonging to Mr. Hermann Smith. Four small bells of which the largest was 45 mm. in diameter and 13 mm. in height, arranged on a stem passing through them and framed in a lyre-shaped wire.

Vib.....	761	912	1004	1156
From vib.....	I	313	II	167
Sums.....	0	313	480	724

The I 313 II is nearly a perfect minor Third of 316 cents. The III and IV give almost precisely the Javese Salêndro observed III 484, and IV 728, so that the interval between them, 244 cents, is almost precisely a Pentatone of 240 cents, or  $\frac{1}{5}$  Octave. If indeed II were flatter, the notes of the bells might pass as part of such a scale.

## IX. JAPAN.

In the Educational Section of the International Health Exhibition of 1884 there was a considerable collection of Japanese instruments, but there were no players. The only instruments which we could try therefore were a Shō (the Chinese shēng (see CHINA, 3), but different in the number and pitch and intervals of the notes) and a Biwa, or four-string fretted lute. The Shō we found to be out of tune, as referred to the scale exhibited, and to be impossible to blow satisfactorily. The Biwa I first tried by measuring the lengths of the strings, and afterwards with Mr. Hipkins, by tuning the strings arbitrarily and taking the pitch from each fret. These results I record, because in addition to the examples from India, they show very well that measurements of lengths are only an approximation to the speaking values of the strings, and that the latter vary considerably with the thickness of the strings. This has an important bearing upon the theoretical determination of scales given by the divisions of the string. The results for India were valuable in this respect, but they were not altogether satisfactory, because the string was English and too thick. In the present case we had the genuine Japanese strings.

The Biwa is a large and heavy but handsome instrument, well made and finished, and answers exactly to Al Fârâbî's lute in Professor Land's "Gamme Arabe," the four strings nearly coinciding at the nut, passing over a semi-circular depression to the large tuning pegs, and spreading out to a convenient distance apart by the bridge, so that the plectrum, made of hard wood, spread out like the head of a halbert, could easily be inserted between the strings, or pass over them in rapid succession for arpeggio chords for which the instrument

seems to be much used in accompaniments, judging from some music written for it in Japan, on the European staff, the original of which I saw. The diameters of the strings, which seemed to be of hard-corded silk, taken by one of Elliott's micrometer gauges, were 1·65, 1·37, 1·06, and 0·88 mm. in diameter respectively. The variations of interval, however, with the thickness of the string appear not to follow any precise law. The frets were high and about 5 mm. wide of the top, made of hard wood. I was very careful to press on the top of the fret, so that the tension of the string might not be increased, and the action should take place from the edge of the fret nearest the bridge. But possibly I may not always have pressed near enough to the edge, so that the string was slightly lengthened and the pitch flattened. Of course nothing like such accuracy would be reached by the player.

Lengths.....	843	750	709	673	637	mm.
From lengths.....	I 202	II 97	III 90	IV 95	V 95	
Sums.....	0	202	299	389	484	

*Lowest string.*

Vib.....	166	189	201	211	223	
From vib.....	I 225	II 107	III 84	IV 96	V 96	
Sums.....	0	225	332	416	512	

*Second lowest string.*

Vib.....	167	190	203	214	223	
From vib.....	I 223	II 115	III 91	IV 71	V 71	
Sums.....	0	223	338	429	500	

*Second highest string.*

Vib.....	226	253	272	286	301	
From vib.....	I 195	II 125	III 87	IV 89	V 89	
Sums.....	0	195	320	407	496	

*Highest string.*

Vib.....	300	339	361	381	401	
From vib.....	I 212	II 109	III 93	IV 89	V 89	
Sums.....	0	212	321	414	503	
Mean from vib.....	I 214	II 114	III 89	IV 86	V 86	
Sums of mean .....	0	214	328	417	503	
Possibly.....	I 204	II 114	III 90	IV 90	V 90	
Sums.....	0	204	318	408	498	

Hence the division was probably meant for Pythagorean, the last sums giving  $C D D\# E F$ , which should have been  $C D E\# E F$ , that is, the second Semitone should have been of 114 cents, and the first of 90 cents. Now it appears from the Report of Mr. Isawa, Director of the Institute of Music, Tokio, Japan (founded October, 1878), an English translation of which, prepared at the Institute, was in the Section, that Japanese theory considers its Semitones to be 12 equal

divisions of the Octave, just as in Europe we so consider our 12 Semitones.\* Hence these divisions are taken, and are used as—

<i>C</i>	200	<i>D</i>	100	<i>E</i> ♯	100	<i>E</i>	100	<i>F</i> ,
0		200		300		400		500

as they would be played on the pianoforte.

This Report contains an account of the Japanese scale, from which, to complete this notice of Japan, although not tonometrically observed, I may cite the following, where all notes may be provisionally considered as those on the piano.

#### Classical Scales.

Riosen .....	<i>D</i>	<i>E</i>	<i>F</i> ♯	<i>G</i> ♯	<i>A</i>	<i>B</i>	<i>C</i> ♯	<i>d</i>
In descending often .....	<i>D</i>	<i>E</i>	<i>F</i> ♯	<i>G</i>	<i>A</i>	<i>B</i>	<i>C</i> ♯	<i>d</i>
Pentatonic .....	<i>D</i>	<i>E</i>	<i>F</i> ♯		<i>A</i>	<i>B</i>		<i>d</i>
Ritsusen.....	<i>D</i>	<i>E</i>	<i>F</i>	<i>G</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>d</i>
Pentatonic .....	<i>D</i>	<i>E</i>		<i>G</i>	<i>A</i>	<i>B</i>		<i>d</i>

#### Popular Scales—Heptatonic.

First Heptatonic .....	<i>D</i>	<i>E</i> ♯	<i>F</i>	<i>G</i>	<i>A</i>	<i>B</i> ♯	<i>C</i>	<i>d</i>
Second „ .....	<i>D</i>	<i>E</i> ♯	<i>F</i>	<i>G</i>	<i>A</i> ♯	<i>B</i> ♯	<i>C</i>	<i>d</i>

#### Popular Scales—Pentatonic.

Hiradioshi .....	<i>G</i>	<i>A</i>	<i>B</i> ♯	<i>D</i>	<i>E</i> ♯	<i>G</i>
Akebono I. ....	<i>G</i>	<i>A</i>	<i>B</i> ♯	<i>D</i>	<i>E</i>	<i>G</i>
Akebono II. ....	<i>A</i>	<i>B</i> ♯	<i>D</i>	<i>E</i>	<i>F</i>	<i>A</i>
Kumoi I. ....	<i>G</i>	<i>A</i> ♯	<i>C</i>	<i>D</i>	<i>E</i> ♯	<i>G</i>
Han-Kumoi .....	<i>G</i>	<i>A</i>	<i>C</i>	<i>D</i>	<i>E</i> ♯	<i>G</i>
Iwato .....	<i>G</i>	<i>A</i> ♯	<i>C</i>	<i>D</i> ♯	<i>F</i>	<i>G</i>
Han-Iwato .....	<i>G</i>	<i>A</i> ♯	<i>C</i>	<i>D</i>	<i>F</i>	<i>G</i>

where observe the numerous examples of the most ancient Greek tetrachord of Olympos, consisting of a Semitone followed by a major Third.

\* Professor Ayrton, F.R.S., who was present when this paper was read, and who had returned from Japan only a few years ago, made some remarks to which with his permission I will here refer. He said that it was a mistake to suppose the Japanese musical intervals to be like the European. He had examined Japanese instruments when tuned in their different ways by natives, and taken the pitches of the notes by means of a siren, and he had found the intervals very different. My paper in this part merely professes to give Mr. Isawa's theory, without citing his confirmatory experiments, which I did not consider conclusive.—A. J. E.